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Kalavai

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(54) **METHOD AND APPARATUS FOR DETECTING AND LOCATING LOOP IMPAIRMENTS**

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This patent is subject to a terminal disclaimer.

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H04M 3/22	(2006.01)
H04B 3/46	(2015.01)
H04M 3/32	(2006.01)
H04M 3/30	(2006.01)

(52) **U.S. Cl.**

CPC ***H04M 3/32*** (2013.01); ***H04M 3/085*** (2013.01); ***H04M 3/30*** (2013.01)

(58) **Field of Classification Search**

CPC H04M 3/085; H04M 3/302; H04B 3/46; H04L 27/263; H04L 27/2634

USPC 379/1.01, 1.03, 1.04, 27.01, 29.01, 379/32.01, 22.01, 22.02, 22.03, 28; 375/222, 227; 324/520, 521, 527, 532, 324/534

See application file for complete search history.

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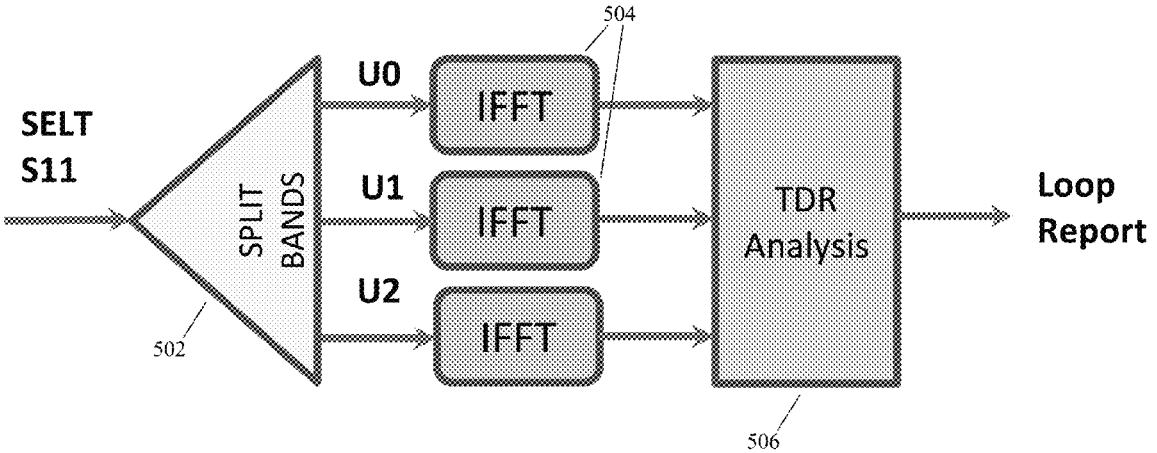
(57) **ABSTRACT**

According to certain aspects, the present invention relates to methods and apparatuses to identify and locate a line-cuts in a loop that may or may not also contain bridgetaps. In embodiments, different bands of SELT signal data are analyzed separately using a TDR method, to effectively detect any potential bridgetaps. In these and other embodiments, by combining information from the separate bands, bridgetap locations and lengths are determined. Methodology is also established to distinguish legitimate line cut or bridgetap signal data from spurious data. According to certain aspects, embodiments of the invention also incorporate baselining, which includes tests to make sure that there are no inconsistencies or imperfections that can corrupt the SELT data.

22 Claims, 12 Drawing Sheets



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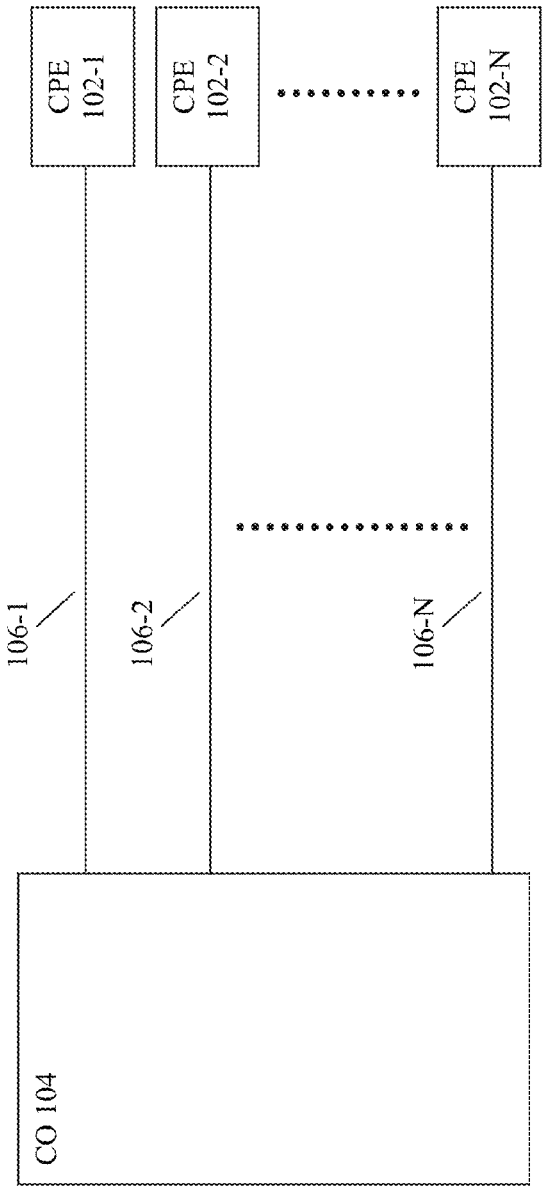
CPE 102-1
CPE 102-2
CPE 102-N
106-1
106-2
106-N
CO 104

FIG. 1

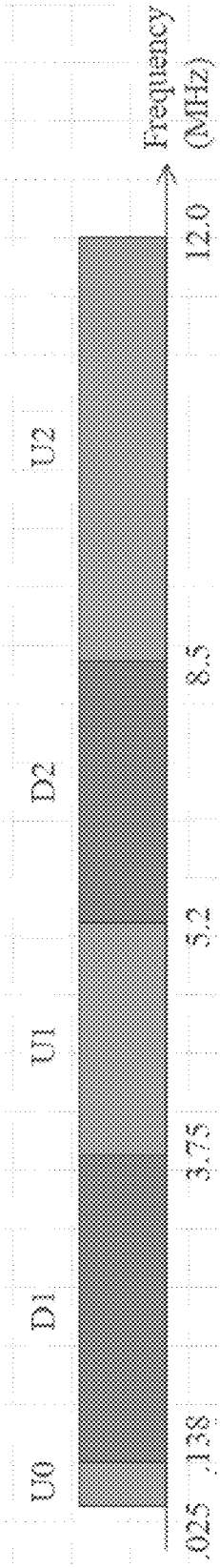
Frequency (MHz)
U0
U1
U2
D1
D2
.025
.138
3.75
5.2
8.5
12.0

FIG. 2

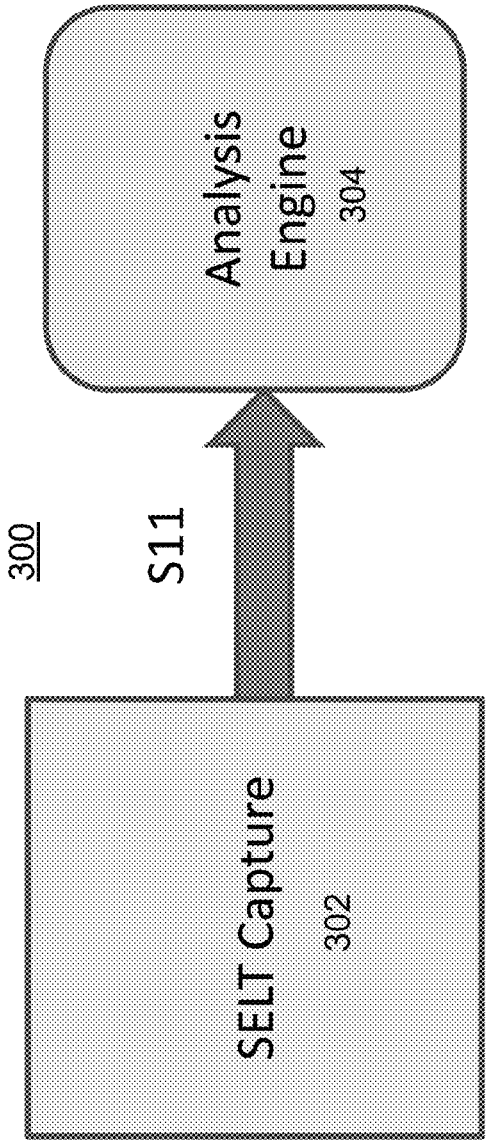
300
S11
Analysis Engine
304
SELT Capture
302

FIG. 3

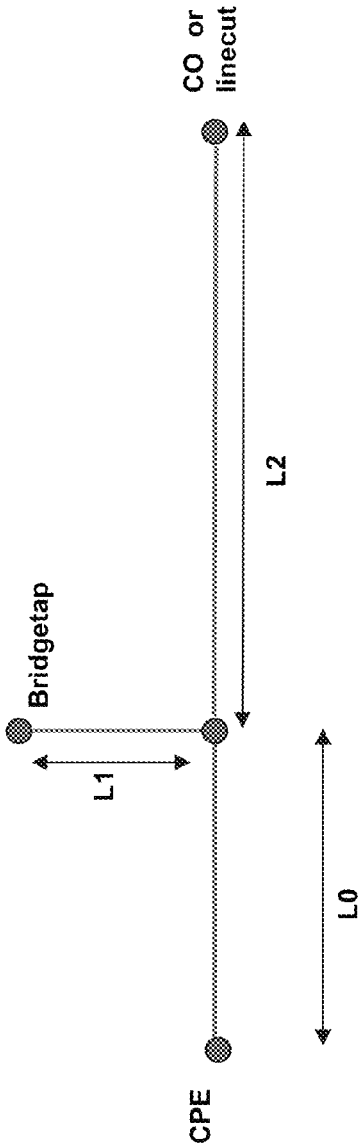
CO or linecut
L2
Bridgetap
L1
L0
CPE

FIG. 4

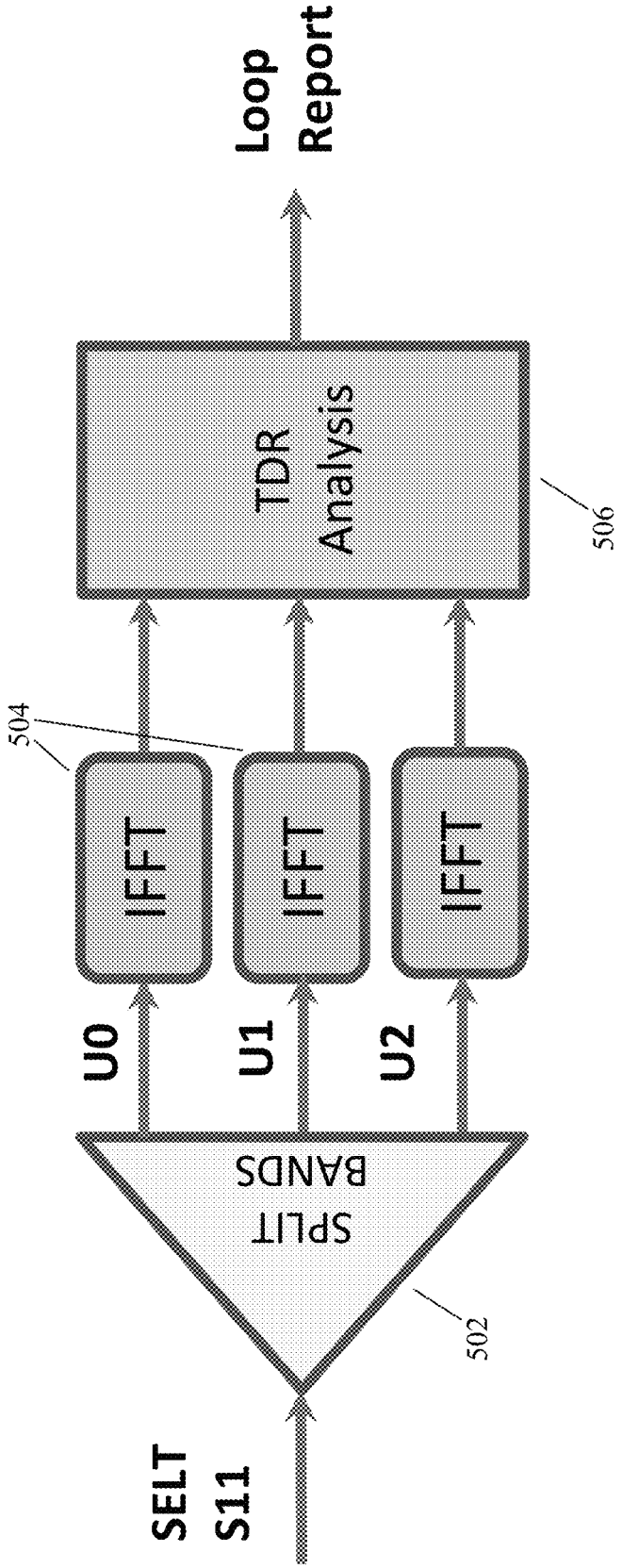
SELT
S11
SPLIT
BANDS
502
U0
U1
U2
IFFT
IFFT
IFFT
504
TDR
Analysis
506
Loop
Report

FIG. 5

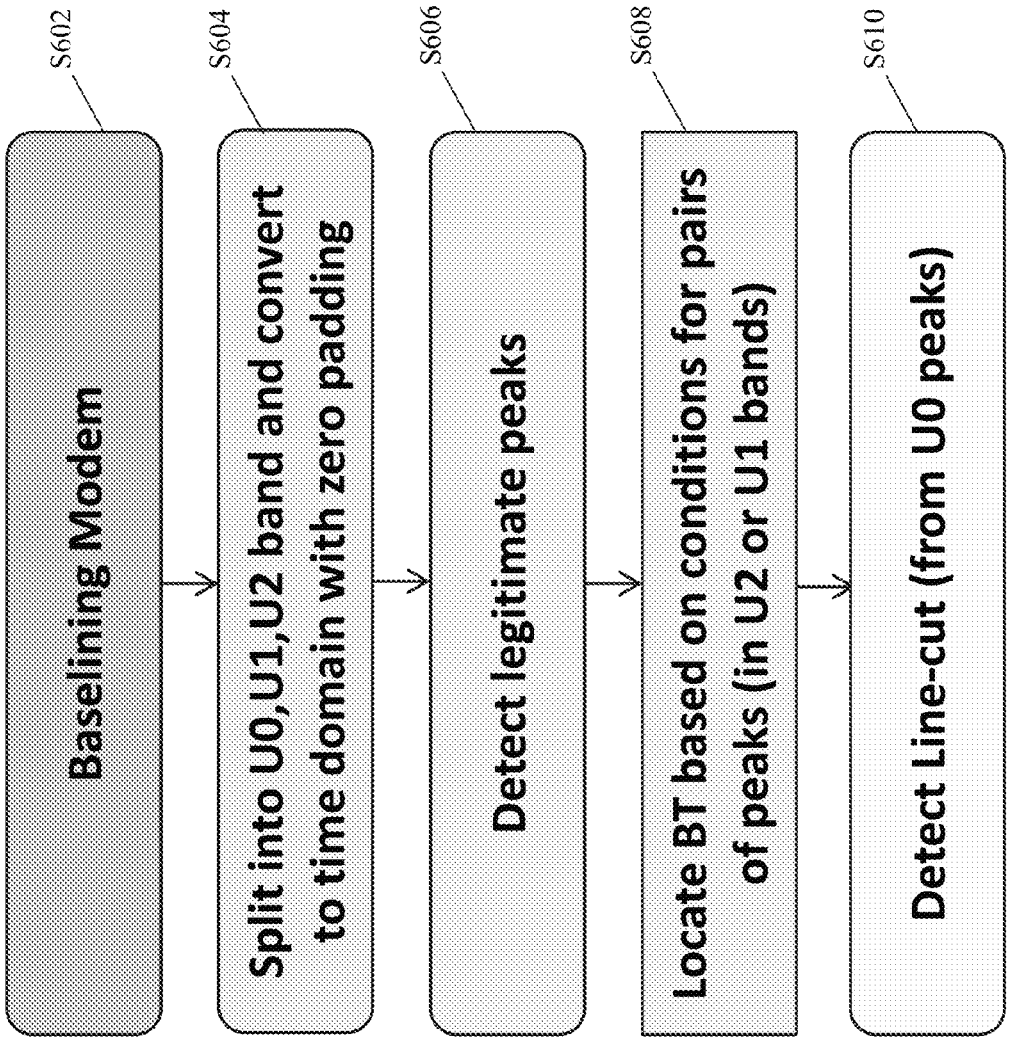
S602
Baselining Modem
S604
Split into U0,U1,U2 band and convert to time domain with zero padding
S606
Detect legitimate peaks
S608
Locate BT based on conditions for pairs of peaks (in U2 or U1 bands)
S610
Detect Line-cut (from U0 peaks)

FIG. 6

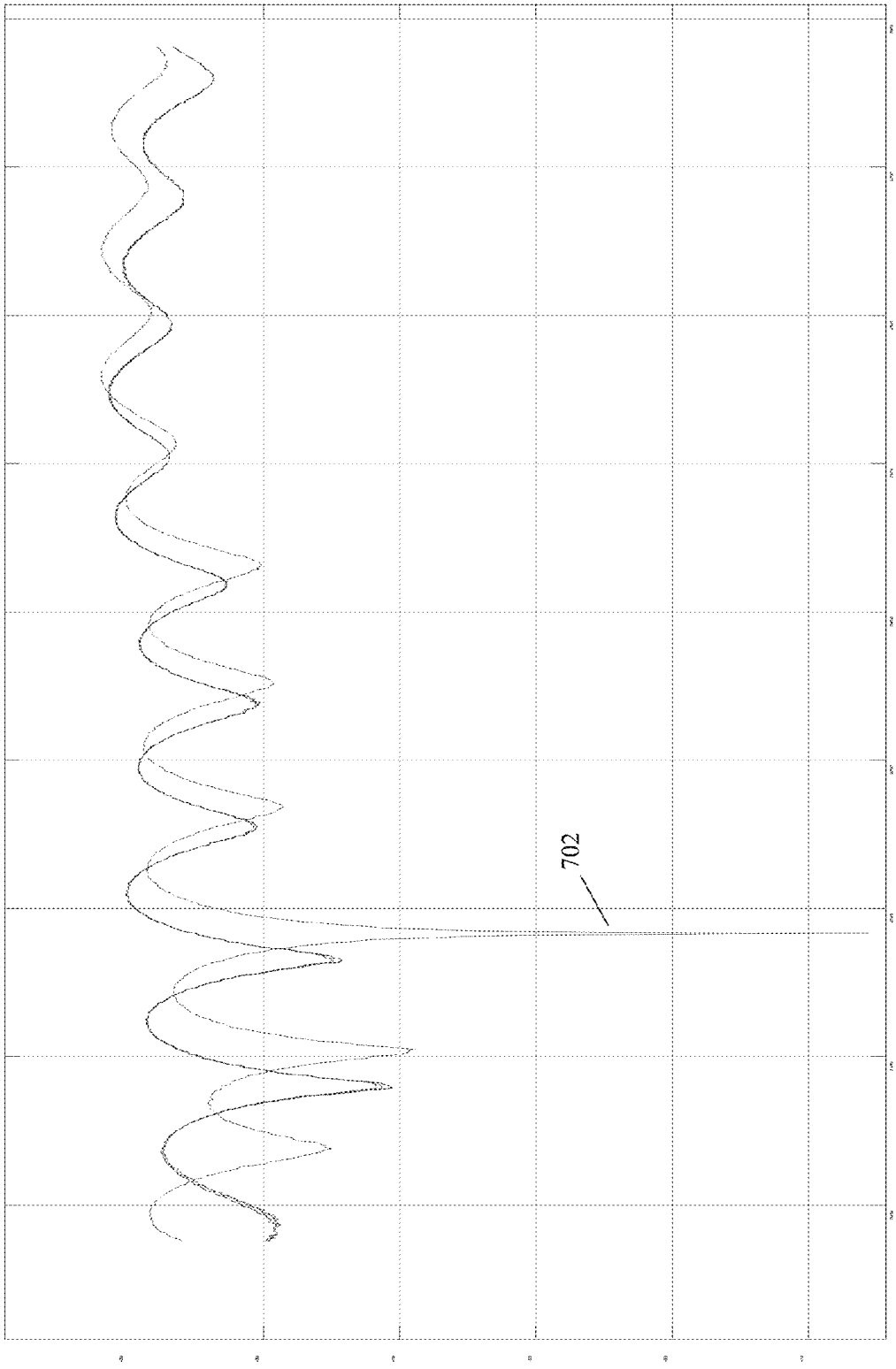

FIG. 7A

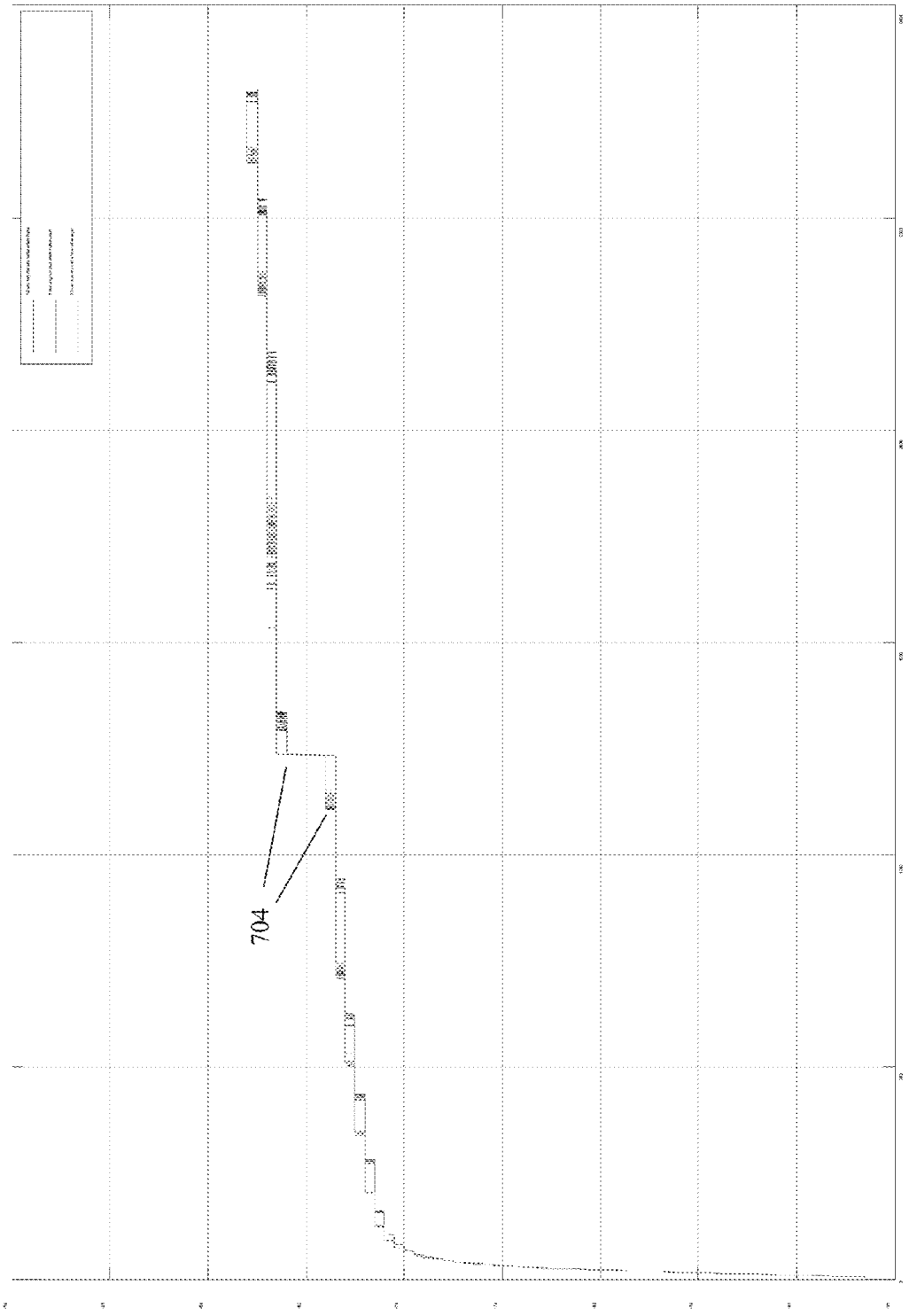

FIG. 7B

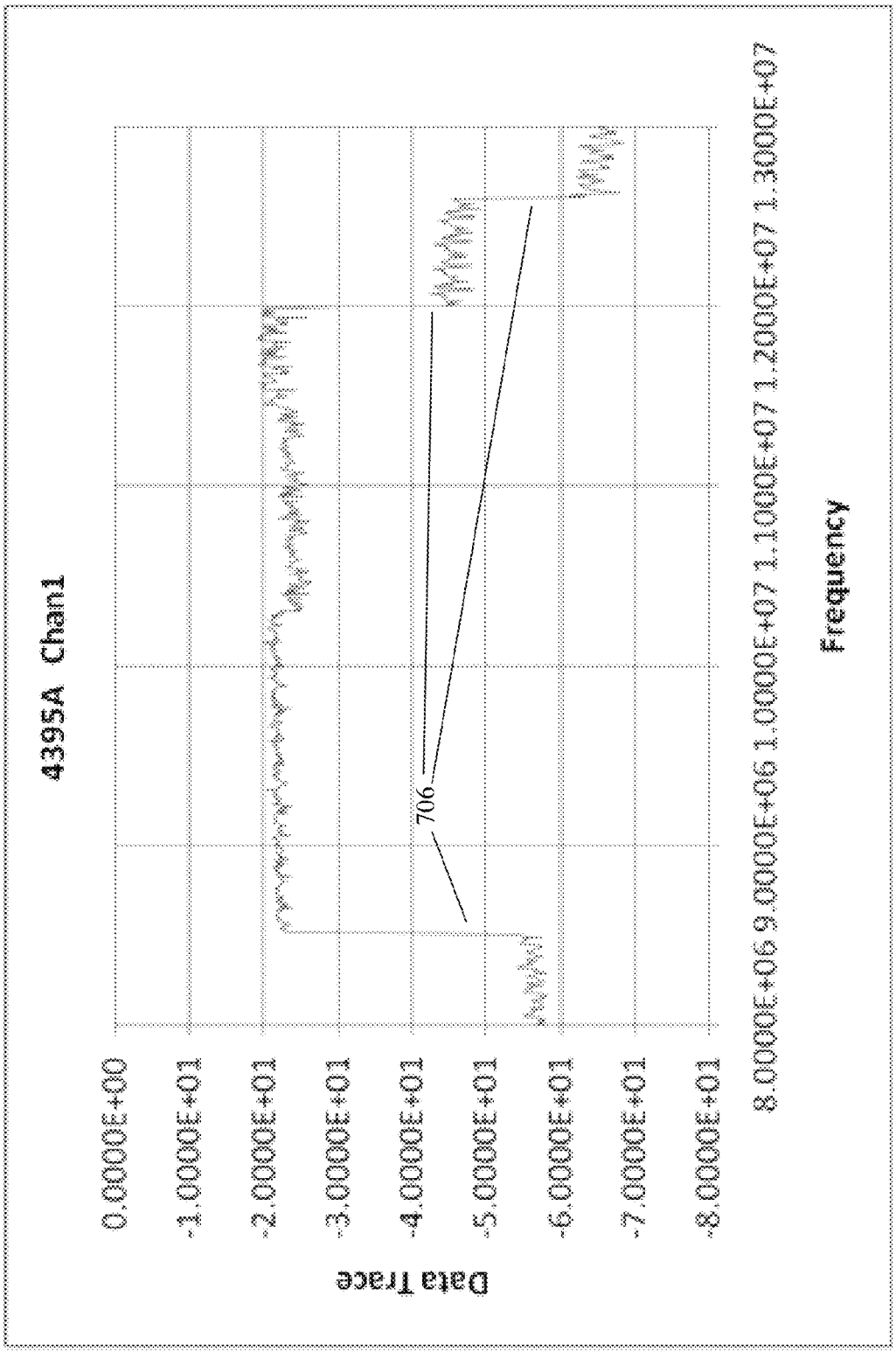
4395A Chan1
Data Trace
0.0000E+00
-1.0000E+01
-2.0000E+01
-3.0000E+01
-4.0000E+01
-5.0000E+01
-6.0000E+01
-7.0000E+01
-8.0000E+01
706
8.0000E+06 9.0000E+06 1.0000E+07 1.1000E+07 1.2000E+07 1.3000E+07
Frequency

FIG. 7C

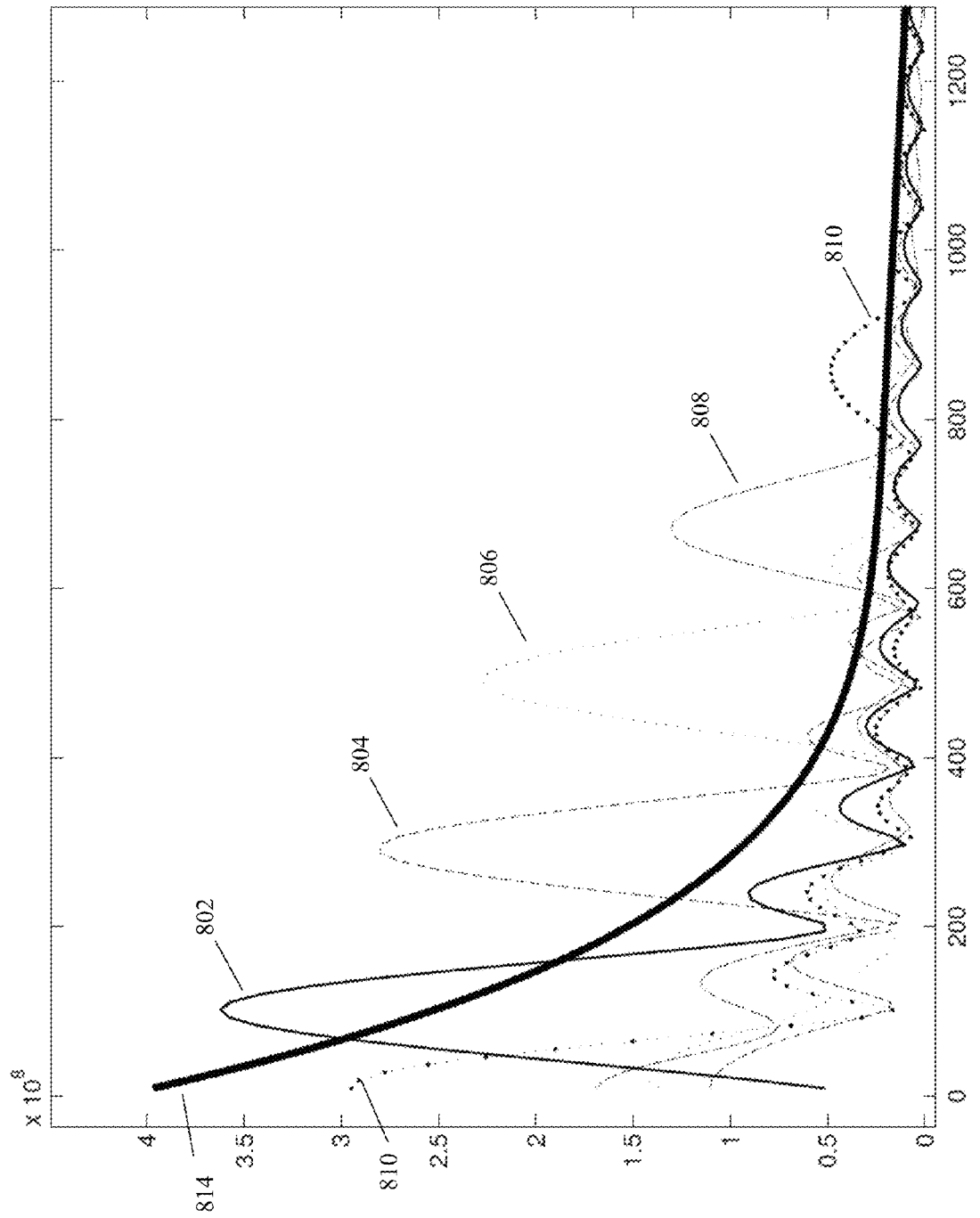
x 10^8
4
3.5
3
2.5
2
1.5
1
0.5
0
0
200
400
600
800
1000
1200
802
804
806
808
810
814
810

FIG. 8

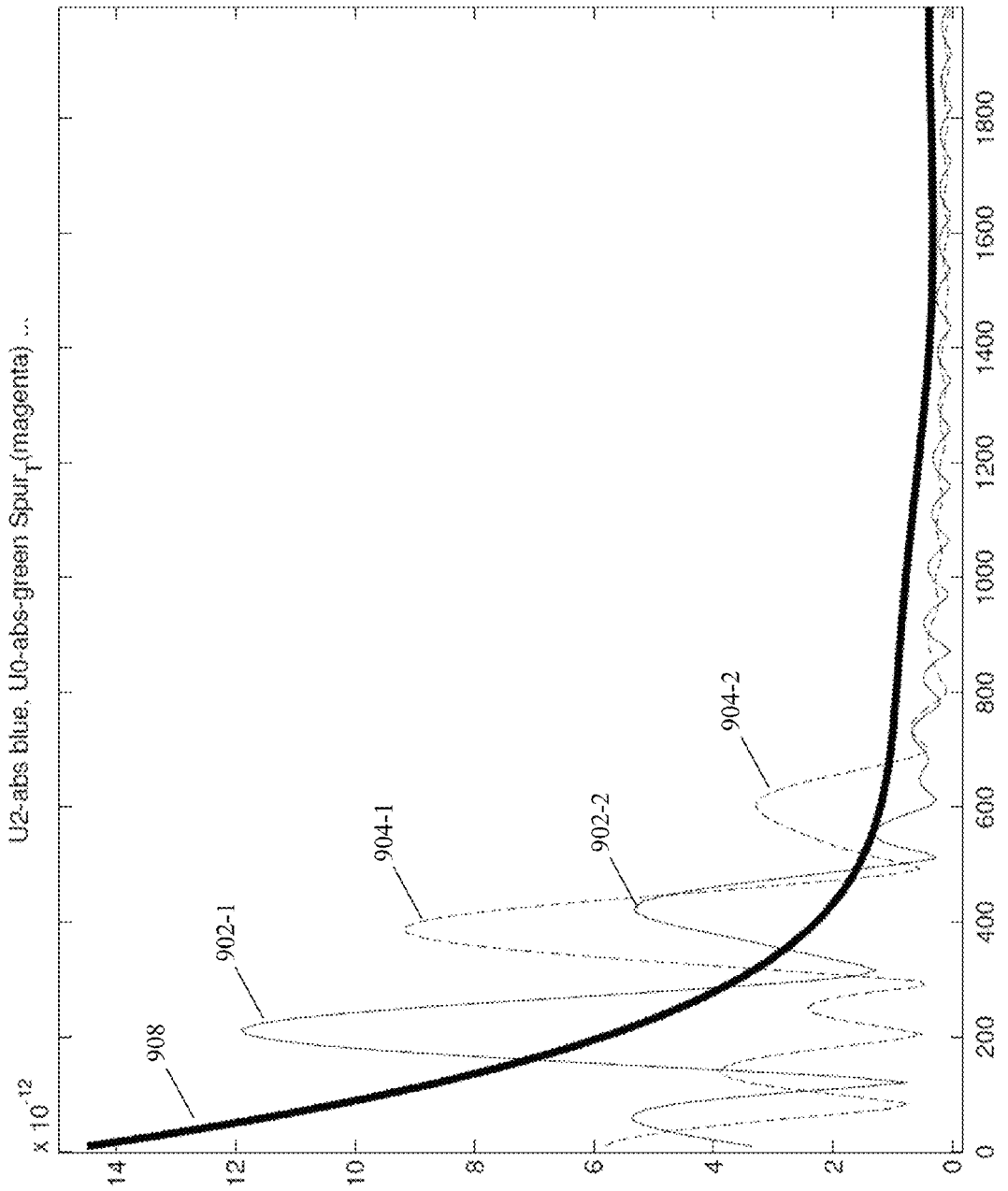
U2-abs blue, U0-abs-green Spur_T(magenta) ...
x 10^-12
908
902-1
904-1
902-2
904-2
0
2
4
6
8
10
12
14
0
200
400
600
800
1000
1200
1400
1600
1800

FIG. 9

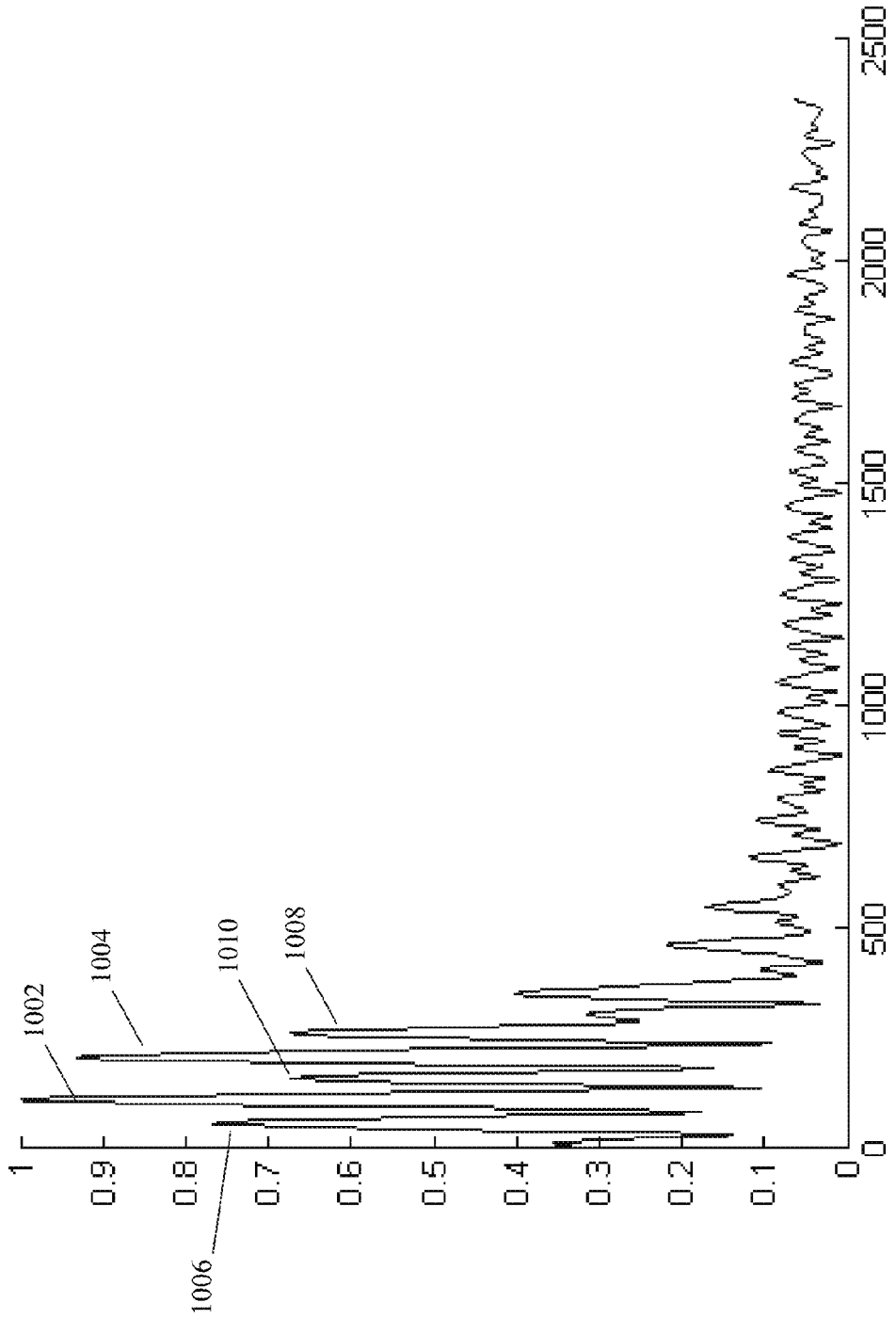
1002
1004
1010
1008
1006
1
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
500
1000
1500
2000
2500

FIG. 10

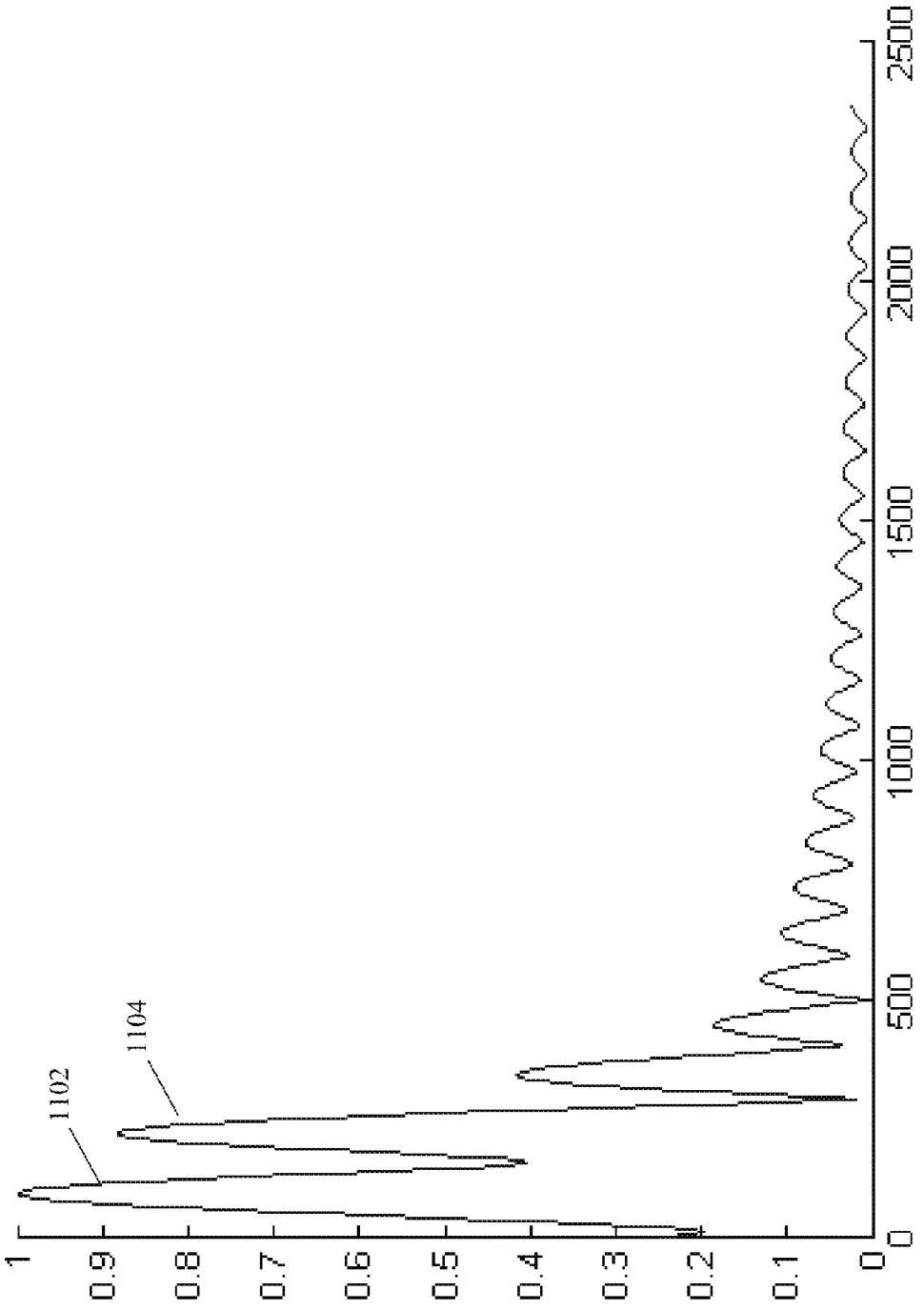

FIG. 11

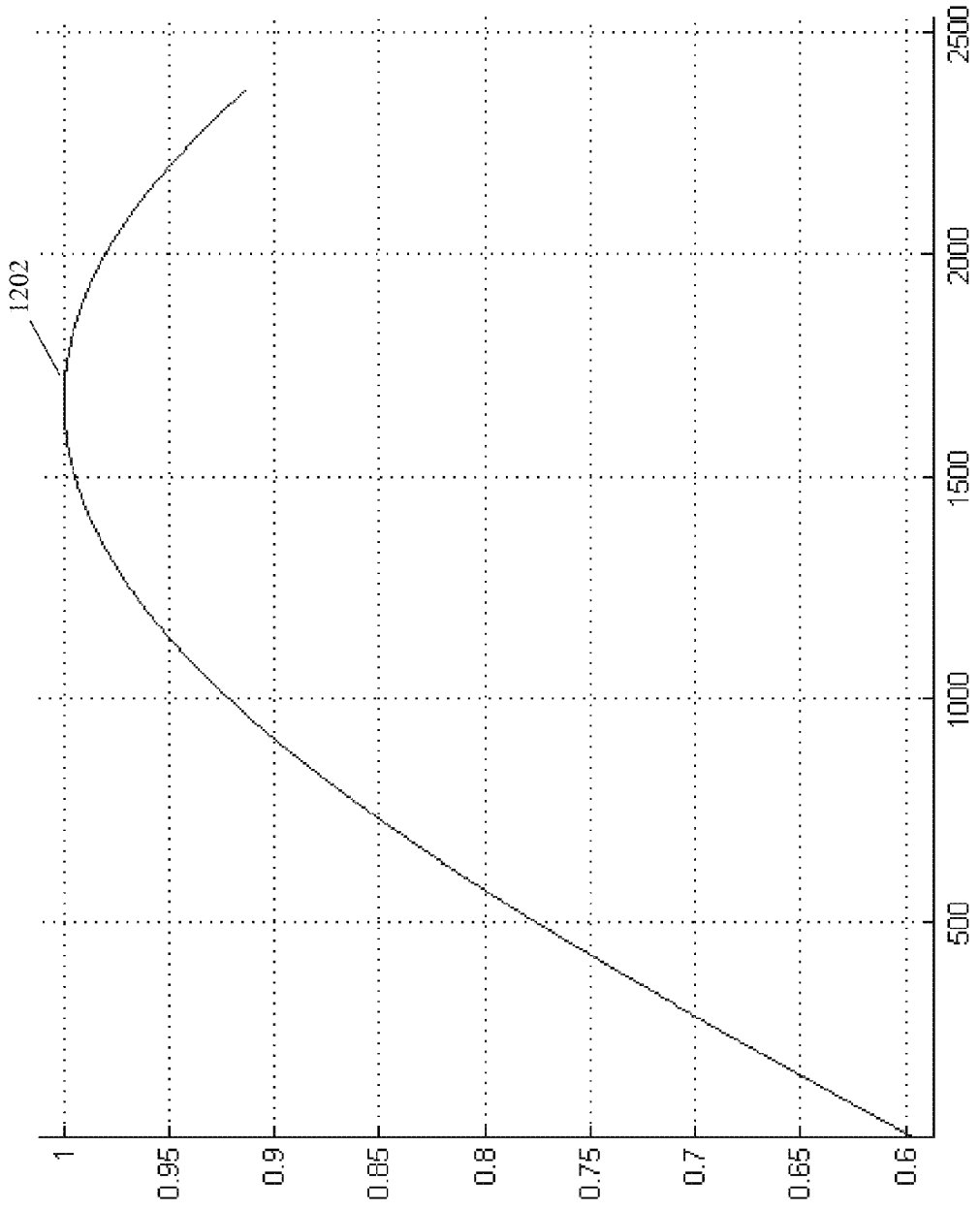

FIG. 12

METHOD AND APPARATUS FOR DETECTING AND LOCATING LOOP IMPAIRMENTS

CROSS-REFERENCE TO RELATED APPLICATIONS

The present application claims priority to U.S. Prov. Appln. No. 61/859,548 filed Jul. 29, 2013, the contents of which are incorporated by reference herein in their entirety.

FIELD OF THE INVENTION

The present invention relates generally to xDSL communication systems, and more particularly to methods and apparatuses for locating bridge taps for loop diagnostics.

BACKGROUND OF THE RELATED ART

In single-ended line tests (i.e. SELT, see, e.g., ITU-T Standard, G.993.2, SERIES G: TRANSMISSION SYSTEMS AND MEDIA, DIGITAL SYSTEMS AND NETWORKS, Digital sections and digital line system—Access networks, Very high speed digital subscriber line transceivers 2 (VDSL2) (February 2006); ITU-T G.996.2, SERIES G: TRANSMISSION SYSTEMS AND MEDIA, DIGITAL SYSTEMS AND NETWORKS, Digital sections and digital line system—Access networks, Line Testing for Digital Subscriber lines (DSL); and "Feasibility and problems of DSL loop topology identification via single-ended line tests", Carine Neus, 16th IMEKO TC4 Symposium Exploring New Frontiers of Instrumentation and Methods for Electrical and Electronic Measurements Sep. 22-24, 2008, Florence, Italy), a known signal is sent over the loop and the reflected signal is analyzed to determine loop characteristics and any impairments present on the line.

One example of a loop impairment is a bridgetap (BT), which is an extraneous dangling cable connected to the line between a customer premises equipment (CPE) and a central office (CO) as a T or a branch. These are typically from configurations that allow the cable company to assign the same main line to different users. A BT on a line between a CO and a CPE causes impedance mismatch and signal reflections leading to a loss in bandwidth capacity on the line. BT's can be a concern to service providers since they typically do not have a historical record of BT locations. If the BT's can be detected and their location and length can be estimated then they can be removed by a technician if required. Hence it would be desirable if SELT could accurately detect bridgetaps and get an accurate loop makeup.

Breaks in a line or line-cuts are additional well-known problems for xDSL systems. These lead to a loss of connectivity and an extensive investigation to fix the problem. Accurately identifying and locating line-cuts using SELT would also be desirable.

SUMMARY OF THE INVENTION

According to certain aspects, the present invention relates to methods and apparatuses to identify and locate a line-cuts in a loop that may or may not also contain bridgetaps. In embodiments, different bands of SELT signal data are analyzed separately using a TDR method, to effectively detect any potential bridgetaps. In these and other embodiments, by combining information from the separate bands, bridgetap locations and lengths are determined. Methodology is also established to distinguish legitimate line cut or bridgetap signal data from spurious data. According to certain aspects, embodiments of the invention also incorporate baselining, which includes tests to make sure that there are no inconsistencies or imperfections that can corrupt the SELT data.

In accordance with these and other aspects, a method for examining a line coupled to a modem in a communications system according to embodiments of the invention includes receiving test signal data from the line for two or more separate frequency bands, separately converting the test signal data to at least first and second different sets of time domain data corresponding to first and second ones of the separate frequency bands, and analyzing the first and second sets of time domain data to identify impairments in the line.

BRIEF DESCRIPTION OF THE DRAWINGS

These and other aspects and features of the present invention will become apparent to those ordinarily skilled in the art upon review of the following description of specific embodiments of the invention in conjunction with the accompanying figures, wherein:

FIG. **1** is a block diagram illustrating an example system in which embodiments of the invention can be implemented;

FIG. **2** is a diagram illustrating an example band plan for which SELT signals according to embodiments of the invention can be adapted;

FIG. **3** is a block diagram illustrating an example loop diagnostics apparatus according to embodiments of the invention;

FIG. **4** is a diagram illustrating example loop characteristic values that can be identified according to embodiments of the invention;

FIG. **5** is a block diagram of an example analysis engine according to embodiments of the invention;

FIG. **6** is a flowchart illustrating an example methodology for identifying bridgetaps and/or line cuts according to embodiments of the invention;

FIGS. **7**A to **7**C illustrate problems that can be found by a baselining procedure according to embodiments of the invention;

FIG. **8** shows peaks in example plots of U**2** time domain data associated with straight loops having line cuts at various locations that can be analyzed by embodiments of the invention;

FIG. **9** shows peaks in example plots of U**2** time domain data associated with loops having bridgetaps at various locations that can be analyzed by embodiments of the invention;

FIG. **10** illustrates an example composite signal that is used in conventional SELT analysis;

FIG. **11** illustrates an example signal corresponding to the signal in FIG. **10** but for the U**2** band only according to aspects of the invention; and

FIG. **12** illustrates an example signal for U**0** band data only for a loop having a 100 ft BT at 100 ft location, and a total loop of 1600 ft.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

The present invention will now be described in detail with reference to the drawings, which are provided as illustrative examples of the invention so as to enable those skilled in the art to practice the invention. Notably, the figures and examples below are not meant to limit the scope of the present invention to a single embodiment, but other embodiments are possible by way of interchange of some or all of the described or illustrated elements. Moreover, where certain elements of

the present invention can be partially or fully implemented using known components, only those portions of such known components that are necessary for an understanding of the present invention will be described, and detailed descriptions of other portions of such known components will be omitted so as not to obscure the invention. Embodiments described as being implemented in software should not be limited thereto, but can include embodiments implemented in hardware, or combinations of software and hardware, and vice-versa, as will be apparent to those skilled in the art, unless otherwise specified herein. In the present specification, an embodiment showing a singular component should not be considered limiting; rather, the invention is intended to encompass other embodiments including a plurality of the same component, and vice-versa, unless explicitly stated otherwise herein. Moreover, applicants do not intend for any term in the specification or claims to be ascribed an uncommon or special meaning unless explicitly set forth as such. Further, the present invention encompasses present and future known equivalents to the known components referred to herein by way of illustration.

According to certain aspects, the present invention relates to methods and apparatuses that accurately and reliably identify and locate line-cuts and BT's in a loop using novel analyses of test signals such as those used in SELT. According to certain other aspects, embodiments of the invention also perform novel forms of baselining, which includes tests to make sure that there are no inconsistencies or imperfections that can corrupt the test data.

FIG. **1** is a block diagram illustrating an example system **100** in which embodiments of the invention can be implemented. As shown in FIG. **1**, a plurality of N CPE transceivers **102-1** to **102**-N are coupled to a CO **104** via respective loops **106-1** to **106**-N. In one non-limiting example, system **100** can be a DSL system operating according to VDSL2, in which certain or all of transceivers **102-1** to **102**-N are configured as a vectoring group by CO **104**. However, the invention is not limited to this example.

As set forth above, in wired communication systems (such as DSL, cable modem etc.) loop diagnostics are often based on analyses of SELT data. For example, CPE **102-1** can perform diagnostics to characterize loop **106-1** using SELT signals transmitted by CPE **102-1** on loop **106-1** and reflected back to CPE **102-1**. Specifically, in an example wherein system **100** is operating according to VDSL2, a conventional SELT performed by CPE **102-1** can include continuously transmitting symbols (e.g. modulated REVERB symbols) each VDSL2 symbol period for a period of about 5 seconds to about 2 minutes, and measuring the reflections (i.e. obtaining S**11** data) from loop **106-1**. It should be noted that some or all of the other CPE's **102-2** to **102**-N can be operating in Showtime using the same symbol periods while CPE **102-1** performs its SELT tests.

The present inventors recognize that in conventional systems such as VDSL2, the CPE is assigned certain frequency bands in which they are permitted to transmit upstream signals according to a prescribed band plan. An example band plan such as that given in the G.993.2 standard is shown in FIG. **2**. As shown, it includes three upstream bands U**0** (comprising tones from 0.025 MHz to 0.138 MHz), U**1** (comprising tones from 3.75 MHz to 5.2 MHz) and U**2** (comprising tones from 8.5 MHz to 12.0 MHz) and two downstream bands D**1** (comprising tones from 0.138 MHz to 3.75 MHz) and D**2** (comprising tones from 5.2 MHz to 8.5 MHz). So symbols constructed by CPE **102-1** and used in SELT can only use tones in the upstream bands U**0**, U**1** and U**2**.

As a result, conventional SELT S**11** data is available only for signals using the upstream bands (e.g. U**0**, U**1** and U**2**). Meanwhile, it would be desirable if SELT could be used to accurately detect the location of BT's since these can reduce the achievable data bandwidth. However, the present inventors further recognize that, due to the banded structure of the conventional SELT signal, it is difficult to detect bridgetap signatures using either frequency domain (FDR) or time domain (TDR) analyses. For example, gaps in the FDR data make it difficult to look for patterns using a FDR analysis. Likewise, discontinuities in the S**11** data create artifacts in the TDR signal and clutter the signatures associated with BT's.

According to certain aspects, therefore, embodiments of the invention include methods wherein signals from one or more of the upstream bands are analyzed separately using a TDR method, to effectively detect bridgetaps. This also helps to exploit the different characteristics of the signal at different bands (for example the velocity of signal changes at different bands). Moreover, by combining information from the separately processed bands, embodiments of the invention can more accurately determine bridgetap locations and lengths, and can more accurately distinguish legitimate peaks from spurious spikes.

It should be noted that the invention is not limited to systems implementing VDSL2 and/or using bandplans such as that shown in FIG. **2**. Rather, those skilled in the art will understand how to implement the invention using other systems, bandplans and/or numbers of bands after being taught by the present examples.

A block diagram illustrating an example apparatus for performing SELT according to embodiments of the invention is shown in FIG. **3**. As shown, apparatus **300** includes a SELT capture block **302** and an analysis engine **304**.

SELT capture block **302** includes functionality for forming SELT signals using symbols (e.g. modulated REVERB symbols) constructed from tones in one or more of the upstream band(s), transmitting the signals on the loop, measuring the reflections from the loop, and providing the S**11** reflection data to analysis engine **304**. SELT capture block **302** can be implemented using techniques known to those skilled in the art, and so further details thereof will be omitted here for sake of clarity of the invention.

Analysis engine **304** receives the S**11** reflection data from capture block **302**. In embodiments, engine **304** analyzes data from each of the upstream bands separately using a TDR method, to effectively detect bridgetaps and line-cuts in the line on which the SELT signals are transmitted and reflected by SELT capture block **302**.

FIG. **4** is a diagram illustrating the values obtained by analysis engine **304** according to embodiments of the invention. As shown, the values include the distance L**0** from the apparatus **300** (e.g. a CPE) to a detected bridgetap, as well as its length L**1**. As further shown, the values also include the distance L**2** between a detected bridgetap and a line-cut or the CO. It should be noted that when a bridgetap is not detected, the distance L**2** is the distance between the CPE and the line-cut or CO.

Example implementation aspects of analysis engine **304** will be described in further detail below.

In embodiments, apparatus **300** is incorporated in CPE transceivers **102**. In these and other embodiments, CPE transceivers **102** (as well as transceivers in CO **104**) include DSL transceivers (e.g. VX180 from Ikanos Communications, Inc.) having conventional processors, chipsets, firmware, software, etc. that implement communication services such as those defined by VDSL2, ADSL2, etc. using a band plan such as that shown in FIG. **2**. Moreover in these and other embodi-

ments, apparatus **300** can be implemented by adapting SELT functionality such as that provided by diagnostics suites such as SmartCPE provided by Ikanos Communications, Inc. Those skilled in the art will be able to understand how to adapt such processors, chipsets, firmware, software, etc. to implement the SELT functionalities of the present invention after being taught by the above and following examples.

It should be noted that in alternative embodiments, apparatus **300** can be incorporated in a standalone loop diagnostics and/or monitoring device, and those skilled in the art will also be able to implement these embodiments of the invention after being taught by the present disclosure.

It should be further noted that embodiments of the invention will be described in connection with SELT performed on a downstream end of lines **106** in or near CPE transceivers **102** using upstream bands. However, the invention is not limited to this example, and such functionality can also be incorporated in or near transceivers at the CO end of lines **106** using downstream bands or upstream bands or a combination thereof.

A block diagram illustrating an example analysis engine **304** according to embodiments of the invention is shown in FIG. **5**.

As shown, engine **304** receives an input SELT S**11** signal, which is essentially the frequency domain representation of the measured reflected signal divided by the transmitted signal, as is well understood by those skilled in the art. This input signal is provided to band splitter **502**, which includes passband filters (i.e. frequency domain windows) corresponding to each of the upstream bands used for the transmitted SELT signal. In the example where the band plan of FIG. **2** is used for the transmit signal, this includes the three upstream bands U**0** (from 0.025 MHz to 0.138 MHz), U**1** (from 3.75 MHz to 5.2 MHz) and U**2** (from 8.5 MHz to 12.0 MHz). As set forth previously, the invention is not limited to this example.

The three frequency domain signals from bands U**0**, U**1** and U**2** are separately converted to time domain signals by IFFT's **504** and the three time domain signals are analyzed by TDR analysis block **506** to produce a loop report which can include, for example, the location and length of BT's and/or the location of line-cuts. Additional implementation features of an example engine **304** such as that shown in FIG. **5** will become even more apparent from the descriptions below in connection with the analysis methods performed by engine **304**.

An example methodology for detecting a bridgetap according to embodiments of the invention is illustrated in FIG. **6**.

As shown in the example of FIG. **6**, before SELT is performed the CPE modem is first checked in step S**602** via a number of tests to make sure the S**11** capture is accurate. This is referred to herein as baselining the modem design. These tests make sure that there are no CPE imperfections or inconsistencies that will affect the SELT data.

It should be noted that the baselining techniques of the present invention are preferably performed in addition to and before standard calibration procedures known in the art to improve the SELT signal. In fact, the present inventors recognize that a calibration procedure itself is not effective, and can even cause degradation of SELT results, without the additional use of baselining according to embodiments of the invention. For example, one version of standard calibration procedures merely aims at determining certain nominal characteristics of a modem itself that can be removed in subsequent processing after the modem is coupled to a loop. These standard procedures typically involve transmitting signals with nothing attached to the I/O ports (i.e. an "open" condition), with the I/O ports directly connected together (i.e. a "short" condition), and with a 100 ohm impedance connected between the I/O ports.

The present inventors recognize that such conventional calibration procedures are not completely effective in identifying certain problems in a modem processing chain when a modem is attached to a loop. Examples of such problems that can be identified using one or more of the baselining techniques in step S**602** according to embodiments of the invention are described in more detail below.

One example technique is related to capture repeatability. In other words, repeated SELT captures with the same loop should yield the same or similar data. In this technique, with the same loop, the SELT S**11** signal is repeatedly measured with power cycling (i.e. power off/on after each measurement), and the measurements are compared. This test will make sure there are no inconsistencies in the Rx and Tx chain that can corrupt the data. An example of such an inconsistency is time delay variation in the Rx and Tx chain. For example, as shown in FIG. **7**A, with repeated captures, the S**11** data showed significant variation (e.g. spike **702** in a plot of one capture) which was later traced to slip between timing of Rx and Tx. Although this problem corrupts SELT, it may not affect the normal modem functionality. Nevertheless, such a problem should be fixed before SELT can be reliably performed.

Another example baselining technique that can be performed in step S**602** is to make sure that the processing in both the Rx and Tx chains are spectrally flat so that they does not introduce any modification of the SELT frequency domain data. Here the Tx and Rx transfer function characteristics are obtained by generating signals at the inputs of the processing chains and spanning the usable frequency spectrum. The outputs of the processing chains are checked using a spectrum analyzer to make sure they are substantially flat across the spectrum. In other words, there should not be any glitches in the transfer function characteristics. Examples of glitches are sudden level jumps or spikes **704** in the characteristics. In the example shown in FIG. **7**B, the Rx transfer function showed a jump in level. As shown in FIG. **7**C, the Tx transfer functions had multiple glitches **706**.

Another example baselining technique is related to signal level consistency. In this regard, the signal gain through the Rx and Tx chains should be fixed for captures, and the AGC settings should be constant or should be accounted for during the SELT capture. This is because the signal level itself is an important signature for SELT. Accordingly, in this example technique, the captured S**11** signal is assured to be independent of any changes in AGC or other signal gain in the SELT capture.

Returning to the methodology shown in FIG. **6**, in the example embodiments described herein, SELT signals are transmitted from the CPE using the VDSL band such as that shown in FIG. **2**, and so there is SELT S**11** data captured for the three upstream bands U**0**, U**1** and U**2** by capture block **302**. As shown in FIG. **5**, and included in step S**604**, the data from the three separate bands in the frequency domain from splitter **502** are converted to time domain by using an IFFT **504** for each band separately. In embodiments, a high IFFT size is used, for example 8192 points. For each of the separate bands, bins corresponding to frequencies outside of the band are zero padded.

Next in step S**606**, TDR analysis block **506** analyzes the time domain signals from each of the three bands and identifies peaks that could possibly correspond to bridge taps or line-cuts. These identified peaks are further analyzed to determine whether they are legitimate peaks.

For example, FIG. **8** shows plots of U**2** data (y axis is time-domain signal level and x-axis is the distance in feet) for straight loops (i.e. loops with no BT's) with a line-cut at 100 ft (i.e. plot **802**), 300 ft (i.e. plot **804**), 500 ft (i.e. plot **806**), 700 ft. (i.e. plot **808**) and 900 ft (i.e. plot **810**). Note that the peaks are generally higher for line cuts closer to the CPE, with the peaks decreasing in level somewhat exponentially with increasing distance. Further note that there are spurious peaks close to the y-axis, particularly for plot **810**. Accordingly, FIG. **7** also shows plot **814** that represents the peak thresholds that are used to identify legitimate peaks associated with line cuts. These thresholds can be determined empirically or theoretically with models, as will be appreciated by those skilled in the art.

In a next step S**608**, bridgetaps are located using the peaks identified in step S**608**. In example embodiments, a bridgetap typically will give rise to two significant peaks in the time domain signal (i.e. TDR signal), one at the location of the bridgetap (i.e. at length L**0** shown in FIG. **4**), and one at the end of bridgetap (i.e. at length L**0**+L**1** shown in FIG. **4**).

For example, FIG. **9** shows plots of U**2** data (y axis is time-domain level and x-axis is the distance in feet) for two loops, one with a 200 ft bridgetap located at 200 ft (i.e. peaks **902-1** and **902-2**) and one with a 200 ft bridgetap located at 400 ft (i.e. peaks **904-1** and **904-2**). There is a final loop section L**2** of 1100 ft in both loops. Similar to the data in FIG. **9**, note that the peaks are generally higher for bridgetaps closer to the CPE, with the peaks decreasing in level somewhat exponentially with increasing distance. As such plot **908** is shown, wherein with increasing distance the peak threshold for determining legitimate peaks declines somewhat exponentially.

An advantage of the multiband analysis approach according to the invention is clearly demonstrated by comparing FIGS. **10** and **11**, which are both plots for a loop having a BT 100 ft BT at 100 ft location, and a total loop length of 1600 ft. FIG. **10** illustrates a TDR composite signal according to the prior art, which includes data for all three bands U**0**, U**1**, U**2**. In comparison, FIG. **11** illustrates a TDR signal for the U**2** band only. As can be seen, the TDR plot of the U**2** band signal in FIG. **11** clearly shows two dominant peaks **1102** and **1104**. Meanwhile, the composite signal plot shown in FIG. **10** also has two dominant peaks **1002** and **1004** but these peaks are now corrupted by strong spurious peaks **1006**, **1008** and **1010**, making it more difficult to determine the number, location and/or lengths of any bridge taps.

It should be noted that there can also be spurious peaks even in the single-banded signals according to the invention such as those shown in FIG. **9** and FIG. **11**. Accordingly, as set forth above in connection with step S**606**, a threshold curve level is determined to separate out real peaks from spurious peaks. The threshold curve level is chosen as the lowest peak level that is obtained due to the presence of a bridgetap or for a line-cut for a given distance.

Moreover, processing in step S**608** preferably includes additional functionality for declaring whether legitimate peaks are actually associated with bridgetaps. For example, if two or more legitimate peaks are identified in step S**606**, it is initially determined that a bridgetap may be present. Next the peaks of the closest pairs of peaks are compared to peak level ratio thresholds that have been pre-determined, for example by empirical tests. This process of comparing pairs repeats until a pair of legitimate peaks satisfies the threshold ratio conditions for a bridgetap. If any such pair is found, the two peaks are declared as denoting the presence of a bridgetap.

Once the location of bridgetaps based on the time-domain samples, a mapping curve is developed between the location of the sample in the time domain and distance in feet (for each of U**1** and U**2** bands). This mapping can be done using conventional benchmarking with known loops in the lab, and programmed into or otherwise provided to the CPE. Applying this mapping to the locations of the identified pair of peaks in the time domain gives the location and length of the bridgetap.

It should be noted that the processing for steps S**606** and S**608** can be separately performed for different bands, and the results combined or compared for accuracy. For example, data from the U**2** band is generally effective in detecting bridgetaps at shorter lengths (e.g. located below 800 ft), while data the U**1** band can detect bridgetaps further away.

As mentioned above, breaks in the cable or line-cut are a well-known problem for DSL systems. This leads to loss of connectivity and an extensive investigation to fix the problem. Accordingly, a next step S**610** shown in the example methodology of FIG. **6** is preferably performed.

The present inventors recognize that given that the U**0** band is a low frequency band, based on the properties of the signal transmission it is minimally impacted by the presence BTs. FIG. **12** illustrates a plot of TDR data for the U**0** band only and for a loop having a 100 ft BT at 100 ft location, with a total loop length of 1600 ft, similar to the loops used in FIGS. **10** and **11**. Note that the U**0** signal of FIG. **12** shows a clear single peak **1202** for line-cut at 1600 ft. Meanwhile, in the composite TDR signal of FIG. **10**, there is no peak at all for the 1600 ft. line-cut. Thus a peak in data for the U**0** band only effectively identifies the presence of a line-cut. It should be further noted from FIG. **12** that BTs do not register peaks in the U**0** data at all.

Accordingly, given the fact that the lower frequencies can travel longer distance with less attenuation, the U**0** band is preferably used in step S**610** according to embodiments of the invention to detect line-cuts which can also be at long distances. For example, the full loop-length (L**0**+L**2**) is determined from the peak **1202** in the U**0** band (as shown in FIG. **12**). A separate mapping curve is developed between the peak position and the distance in feet for the U**0** band. This gives the location of the line-cut in feet.

It should be noted that embodiments of the invention can be practiced together with the SELT functionalities described in co-pending application No. 14/341,576, the contents of which are incorporated herein in their entirety.

Although the present invention has been particularly described with reference to the preferred embodiments thereof, it should be readily apparent to those of ordinary skill in the art that changes and modifications in the form and details may be made without departing from the spirit and scope of the invention. It is intended that the appended claims encompass such changes and modifications.

What is claimed is:

1. A method, implemented by a computer processor, for examining a line coupled to a modem in a communications system, comprising:

receiving test signal data from the line for two or more separate frequency bands;

separately converting the test signal data to at least first and second different sets of time domain data corresponding to first and second ones of the separate frequency bands; and

analyzing, using the computer processor, the first and second sets of time domain data to identify impairments in the line.

2. The method according to claim **1**, wherein the test signal data comprises frequency domain S**11** data.

3. The method according to claim 1, wherein the impairment is a bridgetap, and analyzing includes determining one or both of a location relative to the modem and length of the bridgetap.

4. The method according to claim 1, wherein the impairment is a line cut, and analyzing includes determining a location relative to the modem of the line cut.

5. The method according to claim 1, wherein analyzing includes identifying peaks in one or both of the first and second different sets of time domain data.

6. The method according to claim 5, wherein analyzing further includes comparing identified peaks to a threshold, and declaring identified peaks exceeding the threshold as legitimate peaks.

7. The method according to claim 5, wherein the first one of the separate frequency bands is higher in frequency than the second one of the separate frequency bands, and wherein the identified peaks in the first set of time domain data are used to detect a bridgetap in the line.

8. The method according to claim 7, wherein analyzing includes analyzing a pair of identified peaks to determine a length of the detected bridgetap.

9. The method according to claim 5, wherein the first one of the separate frequency bands is lower in frequency than the second one of the separate frequency bands, and wherein the identified peaks in the first set of time domain data are used to detect a cut in the line.

10. The method according to claim 1, further comprising, before receiving the test signal data, baselining the modem.

11. The method according to claim 10, wherein baselining includes repeatedly capturing test signal data with power cycling to determine capture repeatability.

12. The method according to claim 10, wherein baselining includes obtaining transfer function characteristics of one or both of a transmit and receive processing chains of the modem and determining whether the characteristics are spectrally flat across a usable frequency spectrum.

13. The method according to claim 10, wherein baselining includes determining a signal level consistency of the modem.

14. The method according to claim 1, wherein the modem is a CPE modem and the first and second separate frequency bands are separate first and second upstream bands in a xDSL system frequency band plan.

15. The method according to claim 14, wherein the test signal data is associated with symbols constructed using tones in only the first and second upstream bands.

16. An apparatus for examining a line coupled to a modem in a communications system, comprising:

a capture block that receives test signal data from the line for two or more separate frequency bands;

first and second Inverse Fast Fourier Transforms (IFFTs) that respectively convert the test signal data to at least first and second different sets of time domain data corresponding to first and second ones of the separate frequency bands; and

a Time Domain Reflectometry analysis engine that analyzes the first and second time domain data to identify impairments in the line.

17. The apparatus according to claim 16, wherein the test signal data comprises frequency domain S11 data.

18. The apparatus according to claim 16, wherein the first one of the separate frequency bands is higher in frequency than the second one of the separate frequency bands, and wherein identified peaks in the first set of time domain data are used to detect a bridgetap in the line.

19. The apparatus according to claim 16, wherein the first one of the separate frequency bands is lower in frequency than the second one of the separate frequency bands, and wherein identified peaks in the first set of time domain data are used to detect a cut in the line.

20. The apparatus according to claim 16, wherein the modem is a CPE modem and the first and second separate frequency bands are separate first and second upstream bands in a xDSL system frequency band plan.

21. The method according to claim 1, wherein separately converting includes splitting the received test signal into frequency domain data corresponding to first and second ones of the separate frequency bands.

22. The apparatus according to claim 16, further comprising a band splitter that splits the received test signal into frequency domain data corresponding to first and second ones of the separate frequency bands before the test signal data is respectively converted by the first and second IFFTs.

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